Colorizers Come of Age

A pioneer of electronic image modification examines the tools and techniques of today's equipment

by Bill Etra

Although practically everyone watches color tv, not many people know how the NTSC color system works. And still fewer people are familiar with video colorization, which refers to the addition of color to a black-and-white image or the manipulation and adjustment of colors in a color image. Let's start with basics.

Red, green and blue are the primary colors of light transmission in television. The secondary colors are magenta, cyan and yellow—with blue and green being cyan, red and blue being magenta, and red and green being yellow. The combination of the primaries red, green and blue gives us white, and the absence of all light leaves us with black.

The mixture of primary and secondary colors is not, however, the only way to describe color. Most color television sets, for instance, have controls that describe color by its characteristics—hue, luminance, and color or chrominance. Although there are many additional methods of describing color, just one more should be mentioned. Despite the fact that most broadcast color cameras have three separate tubes—one each for red, green and blue—NTSC color tends to use the Y-I-Q color system. Y is the luminance channel, and I and Q are two separate coordinates, with each containing both hue and chrominance components. Why use the Y-I-Q system? Because the separation of the Y component allows monochrome receivers to get the luminance signal independent of the color components. This also allows the color components to have a limited bandwidth without affecting monochrome resolution.

Color signals have less resolution than monochrome signals. This is because color information signals are added over the monochrome signal. This color subcarrier (3.58 mHz) signal (Figure 1) specifies color by the amount of phase shift and gain difference from a reference signal, or color burst (Figure 2). This color reference signal is generated once every horizontal line, and is formed at the beginning of the line. When colorizing a black-and-white signal we must always consider the loss of detail in color signals versus the amount of clarification added by the separation of levels gained through color coding.

Early colorizers

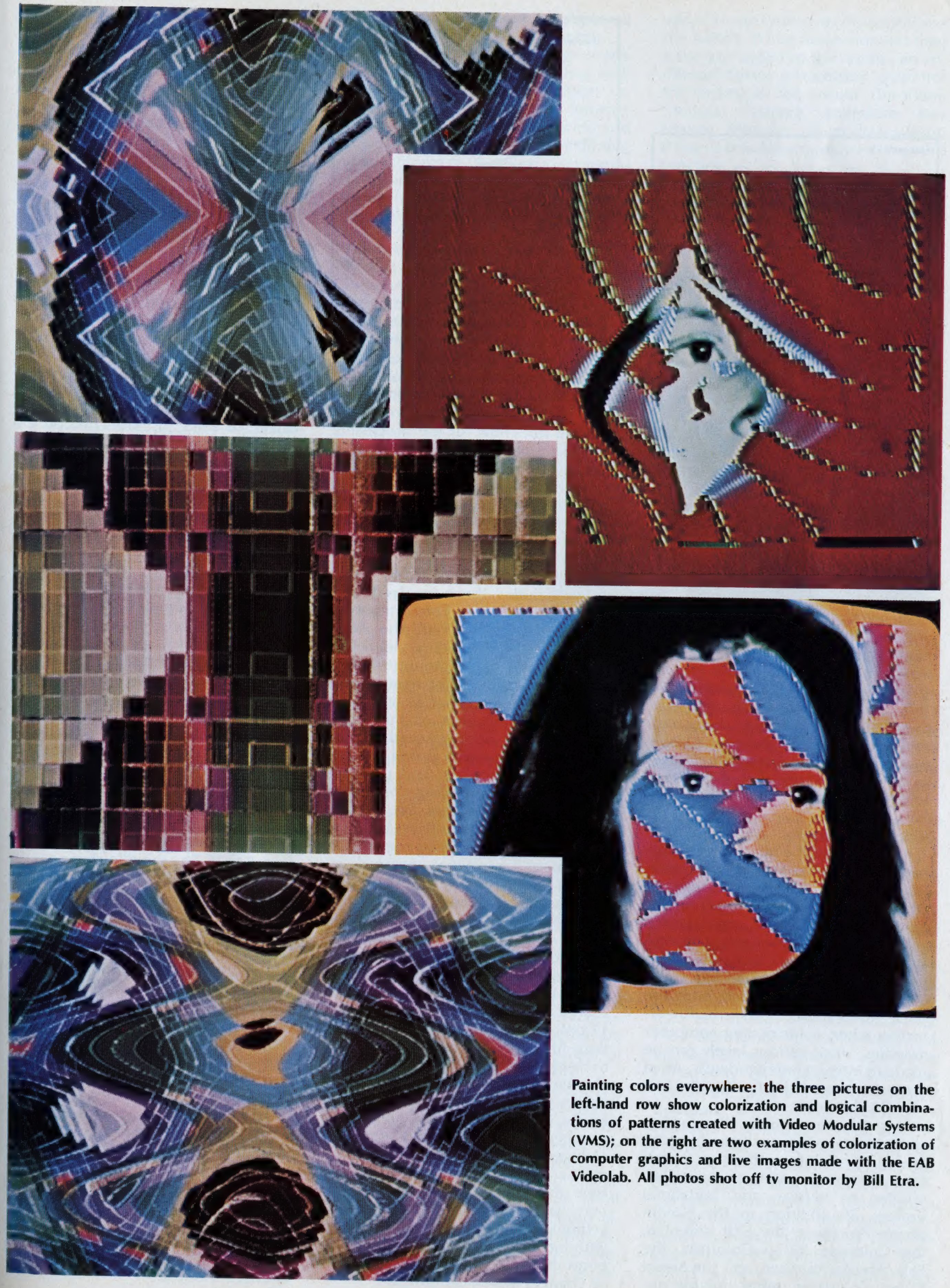
The simplest type of colorizer is one that adds the color burst signals to the picture and modulates the phase of the subcarrier with the luminance of the black-and-white signal. These kinds of machines commonly have controls for chrominance (amounts of color), modulation (the amount of color change caused by the black and white signal), luminance (the amount of black-and-white signal mixed into the output), and tint or hue (the phase of the signal when phase shift initiated).

Early colorizers were almost exclusively of this type. The effects of this type of colorizer can be seen in colorized or tinted black-and-white films. This type of machine produces smooth transitions of subtle shades with most of the black-and-white information visible in the picture. This technique was used in the Riker industrial colorizer, the C.T.L. colorizer built by George Brown, Eric Siegel's early colorizers, and in the first colorizers designed by Bill Hearn for Electronic Associates of Berkeley, Cal. Similar effects can be achieved by using video signals as inputs to a standard RGB encoder (the machine that turns the signals from the guns of a color camera into color). If the same signal is used to drive all channels, and attenuators are present at the inputs, similar effects can be achieved. Video-pioneers Nam June Paik and Shuya Abe used this technique in the colorizer section of their Paik/Abe Synthesizer. They added three more inputs (cyan, magenta and yellow), and allowed for different video signals into each input. They also added a phase shift on the whole system, which essentially changed the color value of each input.

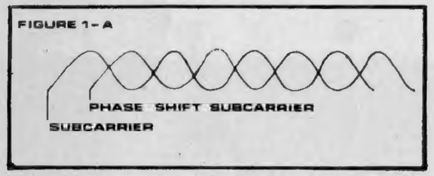
The Image Processor of Chicago video artist Dan Sandin handles all signals as independent channels (**Videography**, December 1976) and, as a last step, puts them into a RGB encoder. Dan's machine goes several steps further, however, since it can process the signal to generate outlines and other complex effects before colorizing. One of the most interesting features of the IP is its ability to do amplitude classification, or quantization. Quantization is the division of the signal into a number of levels. Colors can then be added to each independent level. Most large video switchers use their keyers to quantize the picture, and by keying in color background generators, can colorize the image.

A standard color background generator has controls for hue, luminance,

The author, head of Etra Technology Research Associates Inc. in Oakland, Cal., recently exhibited the system he describes at Video Expo San Francisco.



Painting colors everywhere: the three pictures on the left-hand row show colorization and logical combinations of patterns created with Video Modular Systems (VMS); on the right are two examples of colorization of computer graphics and live images made with the EAB Videolab. All photos shot off tv monitor by Bill Etra.

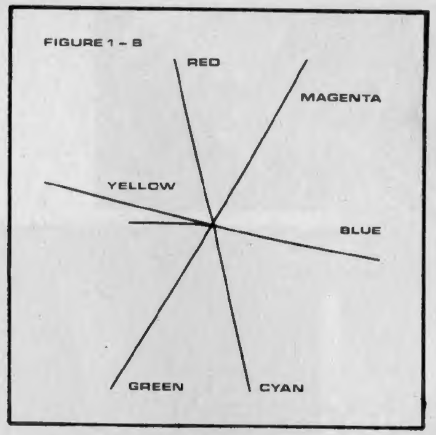


and chrominance. Most switchers however do not have more than four color background generators. Special quantizing colorizers with more levels are used in scientific and medical applications. These commonly have controls allowing for setting color in each level by the amount of RG and B, or hue, luminance and chrominance. Colorado Video Corp. (Boulder, Col.) makes one of the more popular of these devices. A similar unit is used by Computer Image Corp. (Denver, Col.) to colorize their Scanimate machine (**Videography**, November 1977). An improvement on this type of colorizer, although it only quantizes to four levels, is found in the Videolab designed by Electronic Associates of Berkeley, Cal., designed by Bill Hearn and me. This device allows the luminance, chrominance, or hue for each level to be modulated by one or more video pictures. (**Videography**, June 1976). The problem remains however, that in all of these devices, the quantization can only be done to a single source. This means that subtle changes to a color picture are difficult to achieve.

Video synthesizers

In this respect the Sandin Image Processor is a much more flexible device, since it handles R, G and B as separate channels. These can be fed from the guns of a color camera, or a decoded color signal. This allows for quantizing and processing of each channel independently. The red, blue and green channels need not be fed from the same video source. This is highly effective when color coding computer graphics, since various levels can be made to interact independently. All of these features make the Sandin IP a very flexible tool.

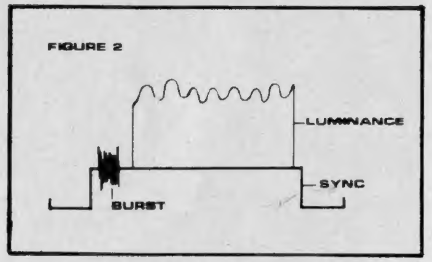
This class of machines, direct video synthesizers, generate shapes by using analog or digital methods to switch color information from on or off, according to vertical and horizontal timings. In addition to the Sandin Image Processor, the EAB Videolab, the Colorado Video Colorizer, the Paik/Abe Synthesizer, and the Siegel Video Colorizers, other notable de-



vices in this category include the Beck Video Weaver, the Chromaton, and the General Electric Genographic System. It should be noted that although devices like the Genographic system offer sophisticated image generation, they do not allow for the processing and manipulation of color and shapes according to input from live video sources. This capability is available in other devices mentioned. Part of the wipe section of many broadcast switchers is now capable of many of these techniques.

Another category of video sythesizers includes those involved with raster manipulation. This category is represented by the Paik/Abe video synthesizer, the Rutt/Etra video synthesizer, and the Computer Image Scanimate system. Raster manipulators alter the time sequence in which we view the raster lines of the video image. This is accomplished by distorting these lines with analog voltages on a special monitor, and then resyncing them by pointing a television camera at the special display.

A similar quality of effects is generated by the newer digital frame store equipment (for instance, that made by RCA, Quantel and Vital). These devices store the video image in digital memory and effectively change the timing of the read or write cycles. All of the devices discussed so far have in common the fact that they are controlled by hand, and operation requires a large number of controls. It requires 15 pots to establish 16 colorizer positions (the bottom position is assumed to be black) and 16 times 3 controls per channel (R, G, B; hue, luminance, chrominance; Y-I-Q), or 36 more knobs, making a total of 51 knobs. The number of knobs allows for slow changes of effects in real time, but makes large overall changes in real time extremely complex. Since you may have to go through undesired settings, change is often impossible without editing. The complexity of controls also tends to make notation of changes extremely difficult.



Manipulating live images

A group of us have recently designed a new system meant to provide the most flexible machine for colorization of both black-and-white and color signals. The system, which is also expandable into a full video synthesizer and video graphics system, is called the Video Modular System colorizer, or VMS. Just launched on the market, VMS units start at about $2,000 without a computer. But because they are infinitely expandable, their prices are also expandable. We have yet to find the system's limits. Those interested in more information should write or call Video Modular Systems, 1440 San Pablo Ave., Berkeley, Cal., 94702. Telephone: 415/527-7700.

The VMS's simplest configuration consists of a three-channel RGB colorizer for black-and-white signals. Three modules are required to accomplish this. They are the analog-to-digital converter (A/D), the digital-to-analog converter (D/A), and the RGB encoder. The A/D converter has four-bit resolution (16 levels.) It samples the video signal at four times color subcarrier (14.3 MHz). At each sample, the A/D decides which of 16 discreet levels the sample is at, and generates an appropriate digital four-bit number from 0 to 16. This sampling happens on three channels (RGB) which may have either the same or different synchronous video signals on them. The A/D Converter uses these three numbers to address a position in a look-up table. The values in the 16 positions of the three look-up tables are loaded from the computer during vertical interval. The values output from the look-up tables are converted into an analog voltage by the D/A Module. There are also look-up tables in the D/A module, but these are ignored when the device is used in this configuration. The analog voltages from the D/A are input to the RGB encoder and turned into color. The RGB encoder genlocks to a video source and provides all sync signals out as well as the 14.3 mHz system clock (for A/D sampling rate, etc.). The signals for the look-up tables (color maps) come from the computer interface module.

Computer interfaces

The interface module is not strictly required for the colorizer configuration but does support the VMS software. The VMS can be used with any number of small computers. The computer interface contains its own Z-80 computer, and systems support is available for connection to the S-100bus, PDP 11-Q and Unibus, Apple bus, TRS-80, as well as IEEE General Purpose Interface Bus (GPIB). For purposes of simplification, the operation of software described assumes the use of a TRS-80 computer.

The colorizer program fills the computer screen with the display in Figure 2. Rows 0 through 15 (bottom to top) are filled with 16 successive columns of R, G, and b's, representing values 0 through 15 (left to right). The final column positions 0 through 15 represent the value selected for R, G and B in that row. If two primary colors have the same value, a "+" is present to represent the overstrike. Values are selected by positioning the cursor over the appropriate R, G or B and hitting the "*" key, which then replaces the R, G or B, which then appears in the appropriate column of the last sixteen positions. Activating the test generator in the A/D box will produce a display on the color monitor. The test display sections the monitor into four vehicle columns, from left to right, Red, Green, Blue and Mixed Color; and 16 horizontal rows, from bottom to top, 0 to 15. This display is the analog of the computer terminal screen. It allows the individual controlling the system to see the results of map changes relative to color. When modules such as the 8-input/3-output switch and the pattern generator are added to the system, the test display can be time-shared with the video input in a number of ways, thus enhancing its usefulness.

The actual information required to load all three colorizer maps is 24 bytes of memory. This means that hundreds of different settings can be stored by even the simplest of home computers.

There are many applications for the VMS colorizer configuration. In laboratories, the VMS colorizer can be used to accent changes in experimental data. A change in physiological signals from an experimental subject can change the color of the subject on the screen. Multiple data signals can be color-coded. Subjects in biofeedback experiments can see results of their efforts by changing screen color. Medical X-rays, thermography and sonograph displays can be colorized and, if desired, the colorization can interact with other biotelemetry. This ability to change colorization from telemetry allows much more data to be displayed and analyzed on a single monitor.

Educational testing can be made more interesting and rewarding with the use of color coding answer responses. The applications in industry are similar to those in medicine and science. Changes in the functioning of machinery can be more easily monitored if color coding is used to indicate changes in temperature, speed and lubrication of machinery. Those

The Video Modular Systems colorizer, consisting of the four boxes at the bottom of the picture, shown in configuration with Radio Shack's TRS-80 home computer and video display. Photo by David Bedel.

observing large factories on monitor displays can instantly see malfunctions and problems in a variety of situations. Similarly, a bank of security monitors can show an intrusion by displaying the area violated in red.

The possible applications of the VMS in the fields of video and photographic art are obvious from the many examples of results using more primitive devices. The major advantage of the VMS for art is that the computer provides the ability to compose and edit the material on a field-by-field basis.

Additional modules

Thus far, we have discussed the most fundamental uses of the Video Modular Systems. As additional modules are incorporated, the potential power of the system grows exponentially.

•The first module to be added to the colorizer configuration is the 8-input/3-output analog matrix switch. This allows any of eight audio or video signals to be used by the colorizer.

•Next, the addition of the digital-pattern generator module (a 24-bit dual-channel phase accumulator) allows for independent vertical and horizontal patterns, as well as logical combinations of these patterns, to be added to the system or control the matrix switch. When more modules than these are added to the system, an additional device is necessary to control the routing of the system. The Video Modular Systems Multiplexer Key Matrix Module, 16-input/4-output, three channel keying matrix serves this function.

•The RGB decoder module allows the colorizer to be used to modify the color of a true color picture.

•The video processing module allows real-time, two-dimensional Fourier transforms between four inputs to be accomplished.

•The VMS Vector display adaptor allows a standard oscilloscopy to generate a vectorscope-type display.

•The video frame buffers have 390x600x4-bit video storage or computer graphic displays.

•The optional PAL encoder module enables the system to be converted to other television system standards.

All of these modules may be added to expand the VMS into a very large synthesizer and computer graphics system. Video Modular Systems has been designed primarily by myself (Etra Technology Research Associates Inc.), Dan Sandin at the University of Illinois/Chicago Circle, and Lee Felsenstein of Golemics, Inc. Lee Felsenstein designed the Sol Terminal Computer which is manufactured by Processor Technology Corp., and the Pennywhistle Modem Kit, distributed by M&R Enterprises. Ned Lagin, our chief engineer and project manager, has been instrumental in the VMS design and fabrication. Bill Hearn, Electronic Associates of Berkeley, Don Day and Michael Polatnick have, as many others, made significant contributions.